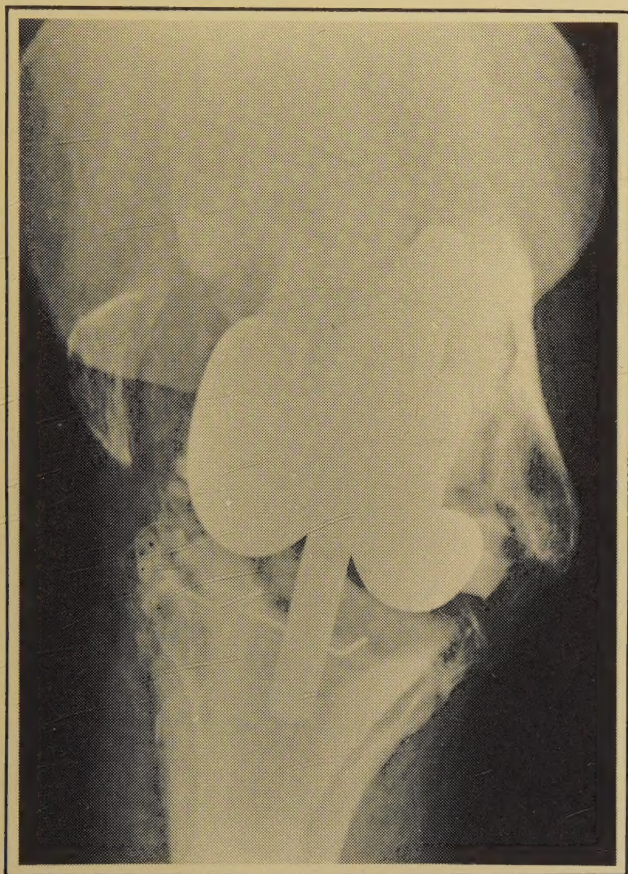


The Failed Knee Arthroplasty



Kaj Knutson

University Department of Orthopaedics in Lund
1985

THE FAILED KNEE ARTHROPLASTY

av

KAJ KNUTSON

leg läk

Smålands Nation

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Handledare

Docent Lars Lidgren, Lund

Docent Anders Lindstrand, Lund

Fakultetsopponent

Docent Sven Friberg, Umeå

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Abstract This study, comprising eight separate investigations, is concerned with knee arthroplasty failure, nerve lesions, tibial component loosening and failure treatment by arthrodesis. 4,505 knee arthroplasties for osteoarthritis (OA) and 3,495 for rheumatoid arthritis (RA) were recorded and reviewed after 1, 3 and 6 years in a nationwide survey. The 6-year survival (i.e. components not being added, removed or exchanged) ranged in OA from 65 % for hinge over 87 % for bi-/ tricompartment to 88 % for lateral and 90 % for medial unicom. prostheses. In RA the 6-year survival ranged from 72 % for medial unicom. to 90 % for bi-/ tricomp. prostheses. - In 498 RA knee arthroplasties performed in Lund the 6-year survival ranged from 76 % for tibial hemi-, unicom. and hinge over 82 % for stabilized to 100 % for tricomp. prostheses. - Radiographic signs of deformed tibial unicom. components occurred in one third of 87 RA knees within 2 years and one fifth of OA knees within 3 years. Thin components were more often deformed. Within 4 years knees with 6 mm components more often required reoperation for loosening than did those with thicker components. - Four peroneal nerve palsies and 3 with only EMG signs of nerve lesion were recorded in 42 RA knee arthroplasties. Correction of flexion contracture and varus shift in alignment predisposed. Two nerve palsies were recorded in 2,273 RA knee arthroplasties in the nationwide survey. - In 91 patient in the nationwide survey with arthrodesis for failed knee arthroplasty two expired from infection and four had amputations. Fusion was achieved in only half of the 109 attempts. The fusion rates was relatively high after unicom. prostheses, in cases with sustained rigid fixation using external double frames or an intramedullary nail, or in cases where infection was brought under control, which was best achieved with gentamicin-beads. - Four case reports illustrated the technique of intramedullary nail arthrodesis for infected knee arthroplasties. A two-stage procedure with temporary use of gentamicin-beads and later massive bone grafting was recommended. - External fixators were biomechanically tested. The AP bending stiffness of the Hoffmann fixator improved with sagittal pins and even more when the latter were connected to ventral frames as in a modified Hoffmann or the similar Ace-Fischer fixator. 19 of 20 patients treated by arthrodesis for failed knee arthroplasty in Lund gained fusion and one patient refused a second-stage operation. Three temporary failures with intramedullary nail or external fixation fused after repeated nail arthrodesis. All 15 infections healed with the two-stage procedure. Three delayed unions fused after prolonged fixation and bone grafting.			
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Date May 9 th 1985

THE FAILED KNEE ARTHROPLASTY

by

Kaj Knutson

Department of Orthopaedics
University Hospital
Lund, Sweden

Lund 1985

This thesis is based on the following publications, referred to in the text by their Roman numerals.

- I. **Survival of Knee Arthroplasties.**
A Nationwide Multicenter Investigation of 8000 Cases.
J Bone Joint Surg, submitted for publication, 1985.
/K Knutson, A Lindstrand, L Lidgren/
- II. **Survival of Knee Endoprotheses for Chronic Rheumatoid and Related Arthritides.**
Acta Orthop Scand, accepted for publication, 1985.
/K Knutson, B Tjörnstrand, L Lidgren/
- III. **Deformation and Loosening of the Tibial Component in Knee Arthroplasty with Unicompartmental Endoprotheses.**
Acta Orthop Scand 52, 667-673, 1981
/K Knutson, G Jónsson, JL Andersen, H Lárusdóttir, L Lidgren/
- IV. **Nerve Palsy after Knee Arthroplasty in Patients with Rheumatoid Arthritis.**
Scand J Rheumatol 12, 201-205, 1983
/K Knutson, I Leden, G Sturfelt, I Rosén, L Lidgren/
- V. **Arthrodesis after Failed Knee Arthroplasty.**
A Nationwide Multicenter Investigation of 91 Cases.
Clin Orthop 191, 202-211, 1984
/K Knutson, L Hovelius, A Lindstrand, L Lidgren/
- VI. **Arthrodesis after Infected Knee Arthroplasty Using an Intramedullary Nail. Reports of Four Cases.**
Arch Orthop Traumat Surg 100, 49-53, 1982
/K Knutson, L Lidgren/
- VII. **Stability of External Fixators Used for Knee Arthrodesis after Failed Knee Arthroplasty.**
Clin Orthop 186, 90-95, 1984
/K Knutson, B Bodelind, L Lidgren/
- VIII. **Arthrodesis for Failed Knee Arthroplasty. A Report of 20 Cases.**
J Bone Joint Surg 67-B, 47-52, 1985
/K Knutson, A Lindstrand, L Lidgren/

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ABBREVIATIONS

CSR = Cumulated survival rate
 OA = Osteoarthritis
 RA = Rheumatoid arthritis

TERMINOLOGY

An arthroplasty is the surgical procedure at which an artificial joint is created and a prosthesis is the artificial substitute.

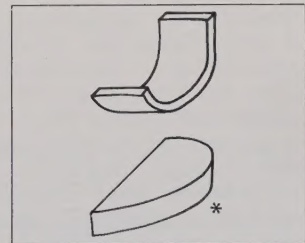
The degenerated articular surfaces are usually replaced. In advanced knee destruction permanent damage to the stabilizing soft tissues and the ligaments may have occurred. This sometimes calls for a stable prosthesis with a connection between the femoral and tibial parts and fixation with intramedullary stems.

The type of connection in stable prostheses or the number of compartments covered by the femoral component in other prostheses is in this investigation used to classify the type of knee prostheses.

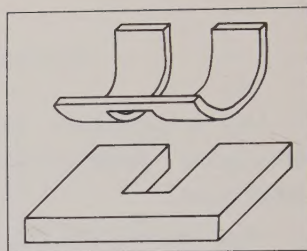
Type of prosthesis

*Tibial hemiprosthesis;
a one-piece unicompartament
prosthesis for one tibial
articular surface (*).*

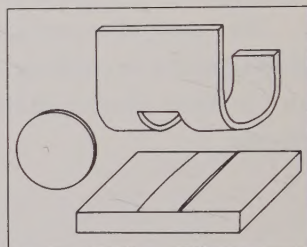
*Unicompartament prosthesis;
a two-piece prosthesis for
the tibial and femoral arti-
cular surfaces of one femo-
ro-tibial compartment.*



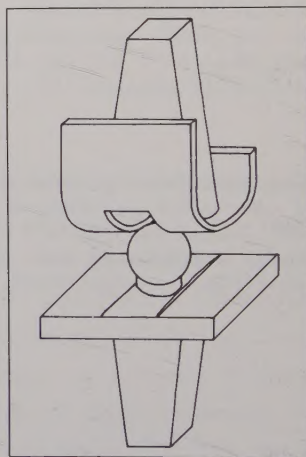
Bicompartment prosthesis;
a two-piece prosthesis with one component for both femoro-tibial surfaces on the femur and the other for the two tibial articular surfaces.



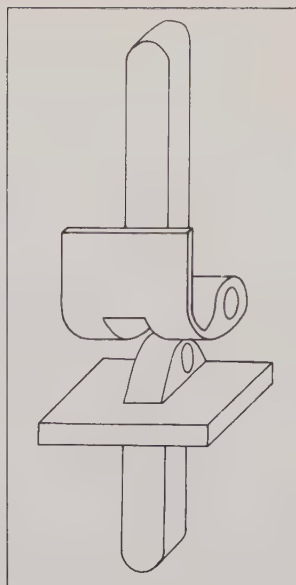
Tricompartment prosthesis;
a two- or three-piece prosthesis with one component for all three femoral and one for both tibial articular surfaces and, as an option, a component for the patellar surface.



Stabilized prosthesis;
a semiconstrained prosthesis permitting flexion-extension and some axial rotation along the tibia, but with a connection restricting the varus-valgus mobility. The prosthesis may be with or without a patellar component and an anterior flange replacing the femoral groove.



*Hinge prosthesis;
a constrained prosthesis
with a fixed axis mobi-
lity, with or without a
patellar component and an
anterior flange.*



Type of arthroplasty

Uni-, bi- and tricompartment arthroplasty describes the extent of the surgical procedure but does not define the actual prosthesis. Hence, a bicompartment arthroplasty could be performed with four uni- or two bicompartment components. Therefore, in order to avoid any misunderstanding, in this study uni-, bi- and tricompartment arthroplasty is equivalent to an arthroplasty using an uni-, bi- or tricompartment prosthesis. A demiarthroplasty is the same as a medial or lateral unicompartment arthroplasty.

Tricompartment, stabilized and hinge arthroplasty denotes the type of prosthesis used without specifying to what extent the patellar articulation was replaced.

INTRODUCTION

The first knee arthroplasties were performed by T. Gluck in Berlin 1890. He used a hinge prosthesis made of ivory with intramedullary fixation using a mixture containing plaster of Paris. These arthroplasties failed and it took more than half a century of operative and biomaterial refinement before a prosthesis was fit for clinical use. Meanwhile, other surgical treatments for advanced gonarthropathy, such as synovectomy, arthrolysis, joint resection, osteotomy and arthrodesis were introduced. Arthrodesis performed with the compression technique (Charnley 1948) became safe and predictable with fusion in more than 95 per cent of the attempts (Charnley & Lowe 1958).

Walldius (1953 and 1957) reported his series of hinge arthroplasties using an acrylic prosthesis. He gradually developed the prosthesis into a cobalt-chromium hinge prosthesis that is still in clinical use. The hinge concept has later been modified into a variety prostheses.

During the 1950's tibial cobalt-chromium hemiprotheses were introduced with promising results (MacIntosh 1966).

Charnley (1960) described the fixation of prosthetic hip components with polymethylmethacrylate. Twelve years later he introduced the low-friction principle in hip arthroplasty with a metal-to-plastic articulation (Charnley 1972). This stimulated the development of a new generation of knee prostheses. The first knee prosthesis with high density polyethylene tibial components articulating against metal femoral components fixed by bone-cement was developed by Gunston (1971). After this step the development was very rapid and by 1973 clinical results were reported for metal-to-plastic hinge, stabilized, bi- and unicompartement prostheses. Later improvements in prosthetic design were the introduction of an anterior flange replacing the patello-femoral groove and a patellar component.

The development of knee arthroplasty has also included the surgical procedure. The old U-shaped Textor incision was replaced by the medial parapatellar and later a straight ventral incision. Detachment of the tibial tubercle, patellectomy and patellectomy have been almost abandoned. Guide instruments, distractors and release procedures for improved alignment and ligament balance have been introduced. Deep infection, a feared complication, has been reduced by sterile enclosure, body exhaust systems and prophylaxis with systemic and local antibiotics (Lidwell et al. 1984).

In the early 1970's considerable clinical experience was reported (Clin. Orthop. 94, 1973). Knee arthroplasty gave pain relief, improved stability and a useful range of motion and was established as an alternative to arthrodesis and osteotomy. There were, however, a wide range of prostheses, changes in surgical technique, contradictory statements on indications and conflicting reports on results with sometimes unacceptably high complication and failure rates. The main complications were still the same as those already experienced by Gluck - deep infection and prosthetic loosening.

For these reasons the Swedish Orthopaedic Society initiated a nationwide survey of knee arthroplasty. Only on such an extensive basis could sufficient material be gathered. The Department of Orthopaedics in Lund was the co-ordinator of the project. The aim was to identify complications and create a foundation for a safer choice of prosthesis (Bauer et al. 1980).

Many reports on knee arthroplasty emphasize the benefits of the procedure. This investigation is focused on the failed knee arthroplasty based on information retrieved from the nationwide multicenter survey and the experiences gained in Lund.

I have investigated

- prosthetic failure related to the type of prosthesis and the preoperative diagnosis.
- loosening of tibial unicompartement components and to evaluate the predictive value of knee scores and early radiographic examination.
- the incidence of nerve lesions after knee arthroplasty for rheumatoid arthritis and to identify predictive factors.
- factors influencing the result of arthrodesis for failed knee arthroplasty.
- if the methods of arthrodesis for failed knee arthroplasty could be improved.

PATIENTS AND METHODS

The Swedish Knee Arthroplasty Project

In October 1975 the Swedish Orthopaedic Society started a nationwide computer survey of knee arthroplasties. All Swedish Departments of Orthopaedics were invited and today 41 are participating.

The project was only intended for registration purposes and had no authority over participants. Participating units have therefore used their own indications for arthroplasty, choice of prosthesis and revision and their own criteria for complications.

Knee arthroplasties performed after the start of the study and onwards have been reported for computer filing. The entry form contained information on knee condition, type of prosthesis local or general antibiotic prophylaxis, duration of the hospital stay and local or general complications during the stay.

Each patient was followed for complications or revisions using a questionnaire one, three and six years after the operation. The questionnaire was answered by the surgeon in charge and patients who reported that they were not satisfied with the operation were seen by the surgeon at follow-up. Soft-tissue and prosthetic revisions were reported using the same entry form as for primary arthroplasties. Secondary arthroplasties were also included in the follow-ups. The date of the death of patients was obtained from the Swedish Central Statistical Office.

A functional evaluation of the knee arthroplasty at the three year follow-up, based on the British Orthopedic Association Knee Evaluation Chart, was used for some years but was later abandoned for the benefit of an extended six year follow-up focused on complications.

Registration and filing of forms have been done at the Department of Orthopaedics in Lund. A Digital Equipment LA 36 printing terminal connected to a Univac 1100/80 computer at the Lund

University Computing Centre has been used since 1979. Each participating unit have received an annual computerized listing of their cases and intermediate results have been presented every year at orthopaedic meetings.

Three investigations were based on the data from the multicenter survey:

- January 1984, 8 000 primary arthroplasties for osteoarthritis and rheumatoid arthritis were analysed for the estimation of prosthetic survival (I).
- May 1981, 2 273 arthroplasties for RA were surveyed for the estimation of the incidence of peroneal nerve palsy (IV).
- January 1982, the computer contained data on 6 342 knee arthroplasties. Ninety-one of these, treated by attempted knee fusion for failure, were retrospectively investigated in detail (V).

The Department of Orthopaedics in Lund

Five investigations comprised patients treated in Lund:

- 498 primary knee arthroplasties for rheumatoid arthritis performed 1967 through 1983 at the Section of Rheuma Surgery and Orthopaedic Infections, were included in an investigation of prosthetic survival (II).
- Eighty-seven patients with classical RA and 107 patients with primary and secondary OA treated with unicompartement prostheses were investigated for tibial component deformation, loosening and revision (III).

- Forty-two consecutive knee arthroplasties performed for RA, 1980, were examined for signs of below-the-knee nerve lesions (IV).
- Twenty consecutive patients treated in Lund for failed knee arthroplasty by knee fusion were studied (VII and VIII).

The survivorship method

The survivorship method or life table technique is well known in medical and technical research. Most textbooks on descriptive statistics include a description of the method (Armitage 1971). A recent comprehensive textbook on survival analyses also includes most valid parametric and non-parametric statistical tests (Lee 1980). The benefit of the method is that it makes full use of all observations instead of excluding some until a certain observation time has been passed. The method allows any well defined event to denote a non-survivor or a failure. In a few reports on survival of hip and knee arthroplasties this method was used (Dobbs 1980, Tew & Waugh 1982, Grimer et al. 1984, Lettin et al. 1984, Lewallen et al. 1984).

In this thesis the survivorship method as described by Armitage (1971) and Lee (1980) was used. Success or survival was defined as the prosthesis remaining in situ at the end of the follow-up regardless of complications and clinical scoring. Consequently, failure was scored for arthroplasties where one or more prosthetic components had been added, removed or replaced. At the end of the surveys (I and II), by December 31, 1983 the status of each arthroplasty was recorded. The length of the follow-up was determined for each arthroplasty either to the end of the survey, the death of the patient or the date of revision or arthrodesis. Survivorship tables were then constructed using a one year interval.

For each year after the primary operation the following was recorded: The total number of surviving arthroplasties entering the interval; the number of failures and the number of successes for patients who had reached the end of their follow-up during the interval; the number of patients at risk of being a failure calculated as the number of survivors reduced by half the number of successes; the yearly probability of survival calculated by dividing the number at risk reduced by the number of failures with the number at risk. Successes and failures were subtracted from the number of survivors to give the number of survivors to enter the next interval. The cumulated survival rate (CSR) was estimated by successive multiplication of the yearly values. The standard error of the CSR was calculated using the Greenwood estimate. Statistical analysis of CSRs was performed with Mantel and Haenzsel's Chi-Square Test (Lee 1980).

SUMMARY OF THE INVESTIGATIONS

Survival of knee arthroplasties. A nationwide multicenter investigation of 8,000 cases (I)

The material comprised 4,505 primary knee arthroplasties for OA and 3,495 for RA recorded in the nationwide multicenter investigation end of 1983. These arthroplasties were analysed using the survivorship method. The most frequent type of prosthesis was Guepar in hinge, Attenborough in stabilized, Freeman prostheses followed by Townley in bi- and tricompartment, and Marmor followed by St. Georg sledge in unicompartment arthroplasties. The choice of prosthesis changed during the eight years studied (Fig. 1 and 2). There was a decreasing use of hinge, stabilized and unicompartment prostheses and an increasing use of bi- and tricompartment prostheses. Demiarthroplasties were, however, regularly performed in about half the cases of OA during the later years. The six-year cumulated survival rates (CSR) were estimated for the six main types of arthroplasty using the survivorship method (Table I).

Table I. Six year cumulative survival rate in 8,000 primary knee arthroplasties for OA and RA.

Prosthesis	Osteoarthritis		Rheumatoid arthritis	
	No at start	Six-year CSR	No at start	Six-year CSR
Hinge	140	65 %	270	83 %
Stabilized	102	83 %	296	84 %
Bi-/ Tricomp	1642	87 %	1962	90 %
Uni Med + Lat	276	87 %	745	84 %
Uni Medial	2051	90 %	114	72 %
Uni Lateral	294	88 %	108	75 %

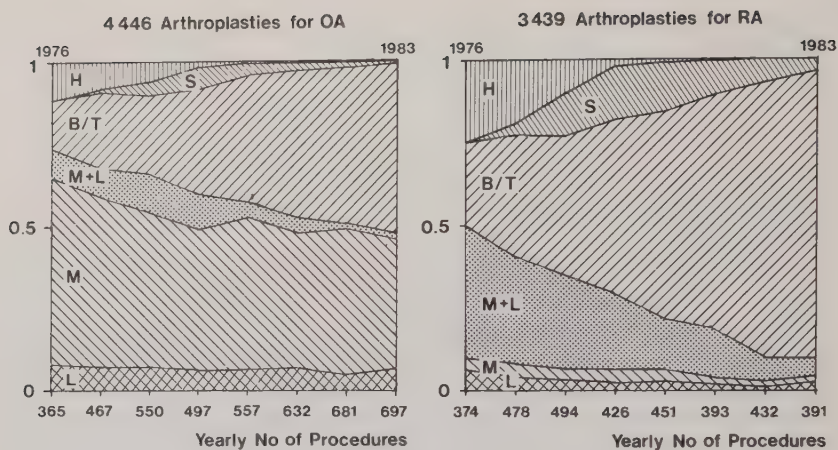


Fig. 1 and 2. The yearly relative distribution of the six main types of primary knee arthroplasty and the annual total number of procedures for OA and RA during 1976 - 1983. Hinge prostheses = H, stabilized pr. = S, bi- and tricompartment pr. = B/T, medial and lateral unicompartment pr. = M+L, medial pr. = M, and lateral pr. = L.

Analysis of different types of prosthesis within each group demonstrated a significantly lower CSR for Freeman prostheses in OA compared with other bi- and tricompartment prostheses (Fig. 3). In RA no discrepant prosthesis could be identified.

The most common reason for failure was loosening of components. The larger prostheses also often failed because of infection, which for bi- and tricompartment prostheses mainly were early infections due to wound healing disturbances. The six-year probability of a revised infection was two per cent in OA and three per cent in RA. One important reason for failure in demi-arthroplasties was, besides loosening, secondary changes in the unreplaced compartment, this being especially pronounced in RA.

The most common type of revision was attempted knee fusion in hinge arthroplasties, replacement with the same type of prosthesis in stabilized and revision with tricompartment prostheses in other arthroplasties. One exception was medial and lateral uni-compartment prostheses in RA that were more often revised to stabilized prostheses because of failure due to instability. The overall six-year probability of an attempted knee fusion as a primary revision procedure was two per cent and of amputation 0.3 per cent.

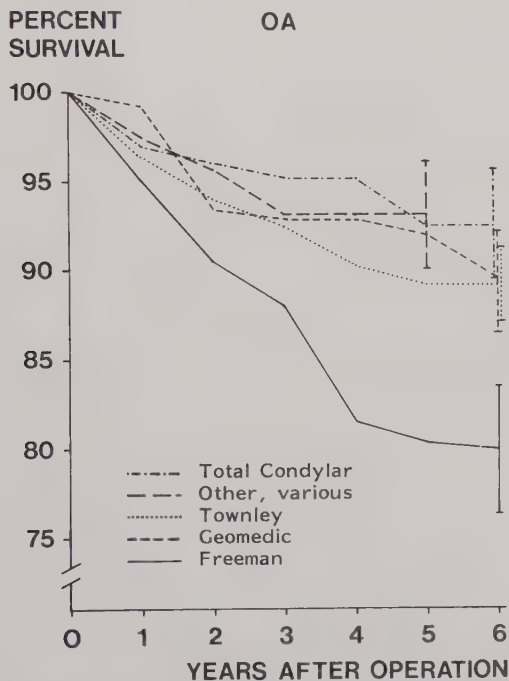


Fig. 3. Estimated cumulative survival rate and standard error at six years after the operation with bi- and tricompartment prostheses of various designs for OA.

Survival of knee endoprotheses for chronic rheumatoid and related arthritides (II)

During a 15 year period 498 knee arthroplasties for chronic rheumatoid and related arthritides were performed in Lund. Failures were treated by exchange arthroplasty in 81 cases, attempted knee fusion in eight and an above-knee amputation in one.

The CSR for 72 MacIntosh tibial hemiprotheses, inserted during 1970 - 73, decreased continuously, falling to 55 per cent at the 11th to 14th postoperative year. Sixty-four hinge prostheses, mainly GUEPAR, inserted during 1967 - 1977 reached a 76 per cent level six to 12 years after the operation. 184 unicompartement prostheses, mainly Marmor, used instead of the MacIntosh prostheses since 1973, reached 72 per cent at eight to ten years after the operation. Stabilized Attenborough prostheses, 89 inserted from 1976, reached 82 per cent in the sixth and seventh postoperative year. The tricompartment prostheses of various types (Total Condylar, Kinematic and P.C.A.) used since 1978 have been applied in 92 arthroplasties with no failure (Fig. 4 and 5).

The most common revision procedure was exchange arthroplasties using the original type of prosthesis when revising hinge and stabilized failures. The stabilized prosthesis was used for revision of failed unicompartement prostheses and unicompartement prostheses for MacIntosh failures.

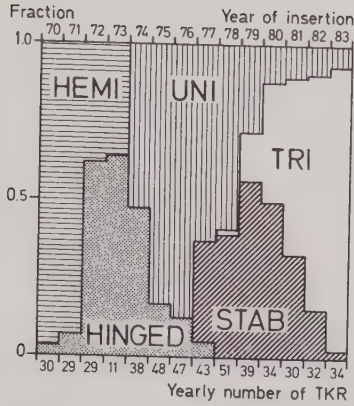


Fig. 4. The yearly relative distribution of the five types of primary knee arthroplasty and the annual total number of procedures for RA and related arthritides used in Lund during 1970 - 1983.

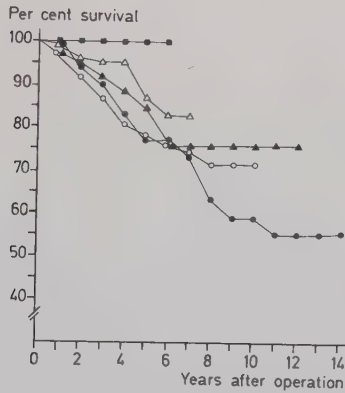


Fig. 5. Estimated cumulative survival rate of five types of primary knee arthroplasty used in Lund for RA and related arthritides. Hinge prostheses = ▲, stabilized pr. = △, tricompartment pr. = ■, unicompartment pr. = ○, and tibial hemipr. = ●.

Deformation and loosening of the tibial component in knee arthroplasty with unicompartamental endoprotheses (III)

Eighty-seven patients with classical RA and 107 with primary or secondary OA, all treated by unicompartament prostheses in Lund, were investigated. In RA all but six were bicompartament arthroplasties, carried out with the modified onlay technique with L-resection of the tibial condyles. In OA all but twelve were unicompartament arthroplasties, carried out with the original Marmor inlay technique. The tibial components used have a thickness varying from six to 21 mm with a three mm increment.

A radiographic assessment was performed after an average follow-up time of 26 months in RA and 40 months in OA. The mainly used Marmor prostheses had a metal indicator wire around the periphery of the bottom of the tibial component in close contact with the underlying bone cement. The occurrence of a broken, twisted or buckled indicator wire was registered, denoting a deformed component-bone-cement interface with partial or total loosening (Fig. 6). A significantly greater number of the 6 mm tibial components in RA and of the 6 and 9 mm components in OA were radiographically deformed and loosened compared with the other components. In RA a total of one-third and in OA one-fifth of the tibial components were deformed.

A clinical assessment was performed at the same follow-up, using knee scores. A comparison was made between knees with and without radiographically deformed components in both RA and OA. No difference in clinical assessment was found.

Reoperations were recorded during an extended follow-up time, the total average being 56 months in RA and 52 in OA. Twelve out of 22 reoperations in RA were performed because of tibial prosthetic loosening. Ten were reoperated after the initial radiographic follow-up and nine of these had radiographic signs of prosthetic deformation at the initial follow-up. The last patient developed signs of deformation during the extended follow-up before the reoperation.

In OA three out of 13 reoperations were done because of tibial prosthetic loosening during the extended follow-up time. All three had signs of prosthetic deformation at the initial follow-up. One more patient, reoperated because of painful development of arthrotic changes in the unoperated compartment of the knee, also had tibial component loosening without preceding radiographic signs. All patients with tibial prosthetic loosening were relieved of pain on weight-bearing after re-arthroplasty.

The clinical relevance of the initial, radiographically detectable, asymptomatic tibial prosthetic deformation is demonstrated by the fact that such findings have preceded 15 out of 16 reoperated cases of tibial prosthetic loosening. The clinical hazard of using the 6 mm component is demonstrated by the large number of reoperations after insertion of this component; 9 out of 72 thin 6 mm components required reoperation in comparison with 9 out of 215 thicker components ($P < 0.05$).



Fig 6. The left knee of a 67-year-old woman with RA four years after a Marmor knee arthroplasty. The thin medial component shows a twisted and broken indicator wire.

Nerve palsy after knee arthroplasty in patients with rheumatoid arthritis (IV)

Forty-two consecutive knee arthroplasties performed in Lund on rheumatoid knees (19 Attenborough, 20 Total Condylar, 3 Marmor) were examined pre- and postoperatively for signs of below-the-knee nerve lesions. No patient had clinical signs of nerve lesion before the operation. Two patients with Attenborough prostheses developed nerve palsies immediately after the operation and one with a Total Condylar prosthesis developed a complete nerve palsy after 2 hours. A fourth patient with an Attenborough prosthesis and a known coagulopathy was symptomless for 5 months but then during training developed haemarthrosis and a total peroneal nerve palsy. Nerve lesions were verified with electromyography (EMG).

A neurophysiological investigation was performed on 16 of the 42 patients, including determination of motor conduction velocities, maximum response amplitudes and EMG. The 16 investigated knees included the two early clinical nerve lesions after Attenborough arthroplasties and three more knees (two Attenborough and one Total Condylar) that exhibited only neurophysiological signs of peroneal nerve palsy. The preoperative examination indicated mild neurogenic changes in four patients but none with denervation activity. Nerve lesion could not be predicted. The postoperative examination revealed denervation activity in muscles innervated by the peroneal nerve in all five patients and also in muscles innervated by the posterior tibial nerve in two. The five patients also showed a significant reduction in response amplitudes, whereas the conduction velocities were only slightly reduced.

The difference in pre- and postoperative varus-valgus alignment was calculated radiographically. The 35 knees without nerve lesion had no mean change in alignment and the seven knees with nerve lesion had a mean change of seven degrees varisation ($P < 0.05$). The extension deficiency was measured with a goniometer pre- and postoperatively when good muscle control was establis-

hed. The mean improvement in knee extension was five degrees in knees without nerve lesion and 20 degrees in knees with nerve lesion ($P < 0.001$) (Fig. 7). The duration of tourniquet use was recorded but had no significance.

From October 1975 to May 1981 the Swedish Knee Arthroplasty Project recorded 43 peroneal nerve palsies in 2,273 rheumatoid knee arthroplasties, which makes 1.9 per cent (ranging from 4.5 per cent in hinge arthroplasties to 0.5 per cent in demiarthroplasties).

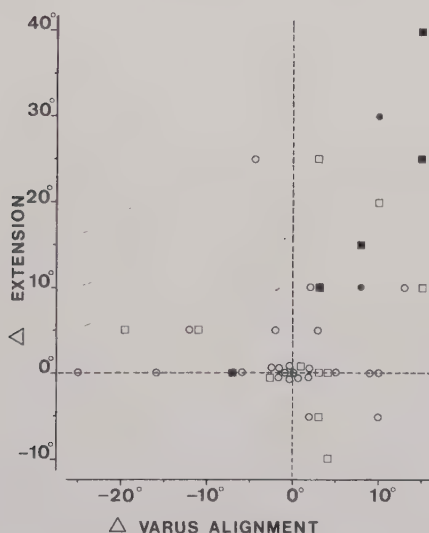


Fig. 7. The difference (Δ) in pre- and postoperative extension, varus (-valgus) alignment, and occurrence of below the knee nerve lesions. EMG-examined knees with nerve lesion ■, and without □. Clinically examined knees with peroneal nerve palsy ●, and without ○.

Arthrodesis after failed knee arthroplasty. A nationwide multicenter investigation of 91 cases (V)

Ninety-one patients with arthrodesis for knee arthroplasty failure were identified in the multicenter investigation. The preoperative diagnosis was primary and secondary OA in 43, RA in 45 and three various diagnoses. Twenty-four patients had been surgically treated in the knee before the arthroplasty and the same number of patients had had an exchange arthroplasty. The failing arthroplasty was a hinge in 36 patients, a stabilized in seven, bi- and tricompartment in 34, a medial and lateral in eleven and a demiarthroplasty in three.

Twenty-five knees were fused for mechanical failures and 66 for infection. Fifty-six infectious failures were classified as proven deep infection because of fistulas in 50 and repeated positive cultures in six. The remaining ten knees with only clinical signs of infection were classified as probable deep infection.

The fixation method at the primary attempt at arthrodesis was external in 82 and internal in nine. The Hoffmann-Vidal frame was used in 41 attempts, the Charnley single frame with additional plaster in 36 and the Charnley double frame in four. Plaster alone was used once. Internal fixation was performed with an intramedullary nail in six, a Rush pin in one and multiple staples in two knees.

A second attempt at arthrodesis was performed in fourteen knees, with a Hoffmann-Vidal fixator in nine, an intramedullary nail in four and a Charnley frame in one attempt. A third attempt was performed with the Hoffmann-Vidal fixator in three knees.

The results of three of the primary attempts could not be classified because the patients died too soon after arthrodesis, one of them in septicemia. Also one of the third attempts was not classified because of an above-knee amputation one month post-operatively due to infection.

The final results were osseous healing in 47, fibrous stable healing in five, fibrous healing with limited instability in ten

and pseudarthrosis in 25 knees. Three pseudarthrotic knees later resulted in an above-knee amputation.

After the primary attempt, fusion was achieved in ten out of 13 knees with a removed unicompartement prosthesis and 32 out of 75 with larger prostheses ($P < 0.05$) (Table 2). The use of a multiple pin fixator resulted in fusion in almost two-thirds and the use of a single frame fixator in fusion in one-third of the primary attempts ($P < 0.05$) (Table 2). The effect of fistulating infection, reduced bone stock due to intramedullary fixed stem prostheses and poor fixation with a single frame and/or plaster on fusion rates was analysed. The fixation method was of major importance and the type of prostheses removed of some importance in determining the outcome of the arthrodesis.

Table 2. Fusion rates after the first attempt at arthrodesis

Prosthesis Removed Fixation Method	Hinge or Stabilized		Bi- or Tri- compartment		Uni- compartment		Total	
	Fused	Total	Fused	Total	Fused	Total	Fused	Total
Charnley single frame	3	15	6	17	2	4	11	36
Multiple pin fixators	11	22	8	14	6	7	25	43
Intramedullary nail	2	2	2	2	1	1	5	5
Other methods	-	2	-	1	1	1	1	4
Total	16	41	16	34	10	13	42	88

Complications were seen in one third each of the attempts with the multiple pin fixators, the Charnley single frame and the intramedullary nail. The external fixation attempts met with pin fracture, loosening of the pins and superficial and deep pin tract infections. Single frame fixation also caused skin necrosis. Intramedullary nail fixation resulted in a tibial fissure and a proximally migrating nail.

Twenty-two out of 29 knees with proven deep infection healed

after a one-stage arthrodesis and general antibiotic treatment. Also ten out of 12 infected knees treated with gentamicin-beads in one- or two-stage procedures healed. Suction-irrigation drainage, synovectomy and two-stage procedures without gentamicin-beads were less effective with healing in six out of 15 cases. Gentamicin-beads were also successfully used in three revisions of initial failures.

The first attempt at arthrodesis resulted in fusion in 22 out of 41 knees where a proven infection was brought under control at arthrodesis. Only three out of 15 knees fused when the infection continued after the arthrodesis and only one out of six when a secondary infection started at arthrodesis. One case of probable infection continuing after arthrodesis failed, the other nine fused.

The functional results were evaluated in 21 patients with unstable and 40 with stable knees. Patients with unstable knees had a median walking distance of 10 - 50 m whereas patients with stable knees could walk 500 m. One third of the patients with unstable knees were nursed in a home for the disabled (Table 3).

Table 3. Follow-up evaluation of the functional results

Arthrodesis Statement	Unstable		Stable	
	No	Total	No	Total
Unsatisfied	6	20	1	39
Pain at rest, slight or more	3	20	8	40
Pain at weight-bearing, more than slight	4	20	2	39
Walking ability limited by arthrodesis	11	20	7	39
Able to climb stairs	7	20	29	37
Able to rise from a chair	15	20	31	36
Support at walking	17	17	29	37
Wheelchair	3	20	1	38
Brace	19	21	1	40
In a home for the disabled	7	21	-	39

Arthrodesis after infected knee arthroplasty using an intramedullary nail. Reports of four cases (VI)

In the treatment of knee arthroplasty failures intramedullary nail arthrodesis may be used to achieve stability if compression arthrodesis is not indicated or has failed.

Four case reports illustrate this technique in the treatment of infected knee arthroplasties. In order to reduce the risk of postoperative sepsis a two-stage procedure was advocated. In the first stage the prosthesis, bone-cement and infected material were removed and the intramedullary cavities filled with gentamicin-beads. Systemic antibiotic treatment according to tissue cultures was given and the knee protected in a dorsal plaster until the wound was well healed.

In the second stage the beads were removed, the medullary canals reamed and a suitably long Küntcher nail inserted from the trochanter. The condyles were chiseled off and decorticated, patella denuded and cancellous bone transplanted. A proximally curved nail and a ventral introduction of the nail in the trochanter gave in two cases better apposition of the condyles.

Postoperatively a brace was used for further protection of the knee. Weight-bearing was started after six weeks and antibiotics continued until osseous fusion was demonstrated. With this regime all four cases fused without postoperative sepsis.

Stability of external fixators used for knee arthrodesis after failed knee arthroplasty (VII)

Five external fixators were mounted on synthetic bones and tested for anteroposterior and lateral bending stiffness in a material testing machine. Four point bending was induced and a X-Y plotter recorded the load-deformation curves. A free gap was left between the synthetic bones to simulate the condition often found in secondary knee fusion where the condyles are eroded and therefore add little to the stability. The test range was within 30 N to avoid permanent deformity. The following fixators were tested: 1) The Hoffmann-Vidal fixator with quadrilateral mounting and six threaded transverse Steinmann pins. 2) As number 1, with the addition of two pairs of sagittal stainless steel pins clamped to a ventral connecting rod. 3) Sagittal and transverse pins as in number 2 connected to ventral frames. A trilateral mounting was arranged with one ventral and two posterior connecting rods fixed to the clamps. 4) The Ace-Fischer fixator with ventral frames and trilateral mounting fixed to the same stainless steel pin configuration as in number 2. 5) The Ace-Fischer fixator mounted as above but with titanium pins.

The anteroposterior bending stiffness was significantly higher in external fixators with sagittal pins (2-5) than in the standard Hoffmann-Vidal fixator (1). The use of ventral frames (3-4) further significantly improved anteroposterior bending stiffness. Lateral bending stiffness was higher than the antero-posterior bending stiffness in all setups.

Table 4. Anteroposterior and lateral stability of external fixators

Type of Fixator	Mounting	Sagittal Pins	Pin Material	Bending Stiffness (kN/cm)	
				A-P.	Lat.
1 Hoffmann-Vidal	Quadrilateral	No	Steel	0.077	1.0
2 Hoffmann-Vidal	Quadri+Ventral	Yes	Steel	0.29	0.88
3 H-V + Ventral frames	Trilateral	Yes	Steel	0.39	0.82
4 Ace-Fischer	Trilateral	Yes	Steel	0.47	0.83
5 Ace-Fischer	Trilateral	Yes	Titanium	0.51	0.79

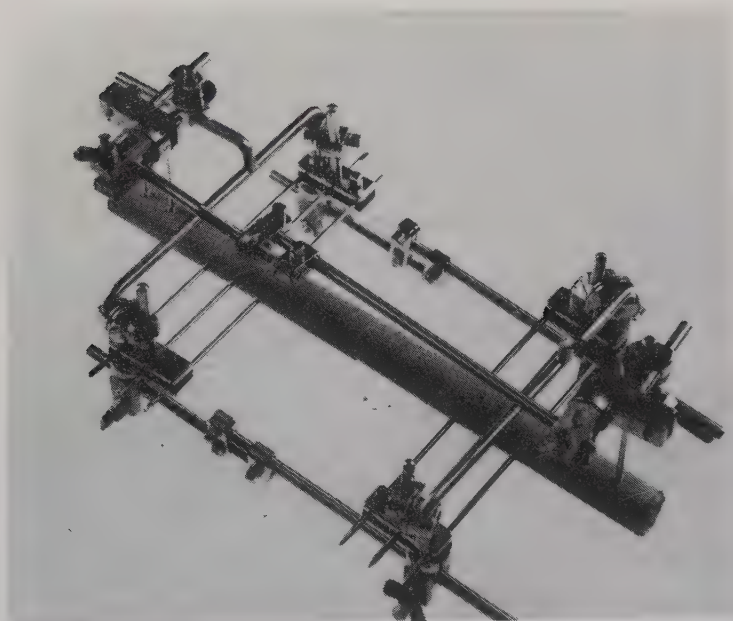


Fig. 8. The modified Hoffmann-Vidal fixator with ventral frames, sagittal pins, and trilateral mounting.

Arthrodesis for failed knee arthroplasty. A report of 20 cases (VIII)

Twenty consecutive patients treated by arthrodesis for failed knee arthroplasty were reported. The initial diagnosis was RA in eleven and primary or secondary OA in nine. Eight arthroplasties had previously been revised by exchange arthroplasty. Eight hinge, five stabilized and seven compartment prostheses were removed for infection in 15 knees, loosening in four and instability in one. Twelve infections were treated by a two-stage procedure using gentamicin-beads. Four mechanical failures were treated by a one-stage procedure. One patient with osteolytic bone destruction was treated by the two-stage procedure although intraoperative cultures were negative. All infections healed.

The Hoffmann-Vidal fixator was used in six attempts at arthrodesis. Two out of three attempts after removal of a hinge prosthesis failed. Three attempts after removal of smaller prostheses were successful. So was also one attempt with the Ace-Fischer fixator after removal of a hinge prosthesis. Nine out of ten primary attempts with intramedullary nail fixation resulted in fusion. The one failure with intramedullary nail fixation was due to proximal migration and breakage of the nail. The knee eventually fused after two more attempts, the second time using a dynamic interlocking nail. Two cases unsuccessfully treated elsewhere by Charnley single frame fixation and the two Hoffmann-Vidal failures were successfully revised using the intramedullary nail technique. Five patients had proximal or distal femoral fractures, four after intramedullary nailing and one after an external fixator. All fractures healed.

Three cases of delayed union fused after prolonged fixation and repeated bone grafts.

One patient, with a cardiac infarction after removal of the prosthesis, later refused operation for arthrodesis and remained unfused.

GENERAL DISCUSSION

Most reports on knee arthroplasty concern short-term or intermediate follow-up evaluations demonstrating the safety of the procedure and its effect on pain, stability and mobility. The importance of using a generally acceptable scoring system, allowing comparison in the evaluation of prosthetic surgery has been emphasized (Jónsson 1981, Liang and Cullen 1984). Unfortunately there has been no consensus regarding the way of reporting results and a variety of scoring systems are presently used.

Definition of failure

Two factors, besides symptom relief, are especially important in the evaluation of knee arthroplasty, namely the failure rate and the possibility of treating the failures, in the more severe cases either by revision with a new prosthesis or an arthrodesis. In order to analyse failure rate both the definition of failure and the way of calculating the rate must be acceptable. So far no generally accepted radiographic or clinical criteria for failure have been defined. The usual way of presenting failure rates, as the fraction of failures after some arbitrary observation time, makes comparison and interpretation of results difficult since failure is time dependent.

The life table technique is a well known way of calculating results in tumour research. Different points of entry into the study and losses of observation are handled. The probability of any event can be estimated as a function of the observation time. The method requires a definite point of entry - the performance of a knee arthroplasty, and a definite point of exit - the occurrence of a failure. A multicenter investigation with many collaborators (I) makes it necessary to use a simple failure definition. Only revision with removal, addition or exchange of prosthetic components met that demand. It could not be disputed if

and when such a failure occurred. Additional definitions of failure have been suggested in earlier reports on prosthetic survival but they were discarded because they were either too vague or too complex for the purpose of this investigation (Grimer et al. 1984, Lettin et al. 1984).

The multicenter investigation

The nationwide multicenter investigation (I) has proved to be a good diagnostic tool for the analysis of prosthetic failure with results in good concordance with similar investigations (II) (Tew and Waugh 1982, Grimer et al. 1984, Lettin et al. 1984, Lewallen et al. 1984). Non-revised complications, as for instance, perioperative mortality and conservatively treated infections were not included. However, this investigation was never meant to substitute detailed reports from participating units.

The specificity of the investigation was undisputably good since the risk of a false report of revision must be minor. The investigation was prospective and the loss of patients at follow-up acceptable (2 - 5 per cent). The widely spaced follow-ups (one, three and six years) were not ideal. Yearly follow-ups would have been safer but were considered too resource consuming. The nationwide extent of the investigation reduced the risk of patients being unknowingly treated elsewhere. The final test of the sensitivity will be the comparison of these results with detailed investigations from the separate Swedish units.

Evaluation of prosthetic survival

The evaluation of survival data must be made with the limitations of such studies in mind. The survival of a knee arthroplasty depends not only on the quality of the surgical procedure and the prosthesis used, but also on the selection of patients. Differences must be expected in bone quality, soft tissue condition, concomitant joint involvement and generalized diseases, physical demands and activity level, especially when OA and RA

are compared. Survival, with the present definition, also depends on whether a revision is in fact performed or not. Hinge arthroplasties, for instance, are often difficult to revise because an exchange arthroplasty is a major surgical procedure and a knee fusion difficult to achieve. It could therefore be assumed that hinge arthroplasty complications are more often conservatively treated than surface replacement complications. Furthermore, a large surgical unit may be more prone to perform revisions because of greater experience, special interest and better equipment and choice of prostheses. Finally, the survival rates should not be evaluated per se; the kind of failures and how they were treated must also be included. Deep infection must be considered a more dangerous complication and a knee fusion a more devastating type of revision.

Prosthetic survival in OA

In the multicenter investigation (I), the analysis of survival rates for the initial six years after the operation in OA strongly supports the present choice of arthroplasty. Demi-arthroplasty produced superior results with low infection rate and few arthrodeses. The use of demiarthroplasties is controversial and diverging results have been reported. Favorable reports have been issued by Marmor (1979, 1984 and 1985), Cameron et al. (1981), Jones et al. (1981), Jónsson (1981), Scott and Santore (1981), Shurley et al. (1982), Bae et al. (1983), and Jackson and Burdick (1984). Less enthusiastic were Insall and Walker (1976), Laskin (1978), Insall and Aglietti (1980) and Mallory and Danyi (1983).

Some reports, comparing medial with lateral demiarthroplasty, show less failure in the lateral arthroplasty, but this is usually based on only a few observations (Laskin 1978, Insall & Walker 1976, Insall & Aglietti 1980, Jónsson 1981). The opposite was found in the present study (I) and has also been reported by others (Cameron et al. 1981, Scott & Santore 1981, Mallory & Danyi 1983).

Many of the reported problems with demiarthroplasty have been technical. The thin six millimetre component has caused a considerable number of failures (Marmor 1979 and 1985, Shurley et al. 1982, Bae et al. 1983, Mallory & Danyi 1983). Postoperative varus alignment has been correlated to failure (Jones et al. 1981). Overcorrection also caused failure by degeneration of the untreated compartment (Laskin 1978) and warnings against this have been issued (Marmor 1979, Jackson & Burdick 1984). The Unicondylar prosthesis, being more constrained than other unicompartments prostheses, was sensitive to malposition (Insall & Walker 1976, Insall & Aglietti 1980). The importance of proper indications was emphasized by Jónsson (1981). Wrong indications for the operation with many primary patellectomies, not solving the extensor pain may have caused the bad results reported by Insall and Aglietti (1980).

In conclusion, the Swedish experience with demiarthroplasty has been favorable. The main problem has been loosening of the tibial components and this could eventually be solved with improved design and fixation. Revision due to secondary joint degeneration was only seen in one fifth of the failures. In earlier reports, with an average follow-up period of at least four years, the revision rate for secondary degeneration averaged 4 (0 - 8) per cent (Marmor 1979 and 1984, Insall & Aglietti 1980, Shurley et al. 1982, Bae et al. 1983, Mallory & Danyi 1983, Jackson & Burdick 1984).

Good results in this study were also achieved with tricompartment prostheses and the same has been reported by others (Insall et al. 1983 and 1985, Aglietti & Rinonapoli 1984, Ritter et al. 1984, Townley 1985). With tricompartment prostheses it is possible to treat even severely damaged OA knees leaving very few for the stabilized prostheses. In OA the hinge arthroplasty gave unacceptably poor results indicating that it should not be used (Hui & Fitzgerald 1980, Aubriot et al. 1981).

In medial demiarthroplasty for OA, inferior results were demonstrated in the group of various prostheses where three

fourths had a polyacetal (Delrin^R) tibial component. This material may have played a part in these failures and has been used in an abandoned hip prosthesis with a remarkably high failure rate (Sudmann et al. 1983)

Among bi- and tricompartment prostheses for OA, the Freeman prostheses were identified as an inferior type of prosthesis. A high failure and revision rate was also reported by Goldberg and Henderson (1980) and by Tew and Waugh (1982) when using the ICLH prosthesis. Early Freeman prostheses diverged from other bi- and tricompartment prostheses by the lack of an intercondylar notch and a femoral groove for patellar tracking. Reported reasons for failure were also a too small tibial component causing anterior subsidence, the lack of alignment devices and release procedures, the attempt to obtain slight varus (neutral femorotibial angle) and the negligence of tibial rotatory alignment (Bargren et al. 1983). The prosthesis has been changed and today includes both an intercondylar notch, a femoral groove and a full range of guide instruments (Freeman et al. 1985).

Prosthetic survival in RA

In RA the use tricompartment prostheses seems well motivated (I)(Laskin 1981, Sledge & Walker 1984). Levai and Freeman (1983), however, emphasized the high rate of patellar instability when using the ICLH prosthesis for RA. Demi-arthroplasties resulted in a large number of revisions due to derangement of the untreated compartment. Medial and lateral unicompartment prostheses are too unconstrained to control instability and are inferior to bi- and tricompartment prostheses. Severely deranged RA knees needing an intrinsically stable prosthesis are better treated by a stabilized than a hinge prosthesis. The former had fewer failures and a smaller number treated by knee fusion. Restricted use of the Attenborough stabilized prosthesis has, however, been recommended due to a high potential failure rate (Boegård et al. 1984).

The higher rate of infectious failures in hinge compared with stabilized arthroplasties (I)(Poss et al. 1984) may reflect an

increased risk when using a bulky and constrained metal-to-metal prosthesis. The lower rate in stabilized arthroplasties could also be explained by a general improvement in asepsis and infection prophylaxis in this later introduced prosthesis. Medial and lateral unicompartement prostheses were also mainly used in the early period of the study but with a significantly lower infection rate. This supports the assumption that the size of the prosthesis contributes to the risk of infection. From this follows that when two acceptable prosthetic alternatives exist, the smaller prostheses should be chosen. The total infectious failure rate was higher in RA (3 per cent) than in OA (2 per cent)(II) and the same has been reported for haematogenous prosthetic infections (Blomgren et al. 1985).

The elimination of arthroplasties by failure as a function of time may be divided into three orders, early elimination of suboptimally performed procedures, scattered elimination due to trauma and haematogenous infection and late elimination due to wear and degeneration. In the long-term follow-up of RA (II), tibial hemi-arthroplasties failed constantly during eleven years, mainly because of degeneration with femoral attrition starting early. At six years the CSR of hinge, stabilized and unicompartement prostheses reached a plateau level at six years. Six years may be regarded as the period of early elimination due to operative failures (Herberts & Andersson 1982). The good results in tricompartment prostheses (II) could then reflect the improved surgical technique and an extended observation time is needed to evaluate the wear characteristics of these prostheses. Support for these assumptions was found in a recent long-term survival investigation of Polycentric prostheses (Lewallen et al. 1984). They reported that survival markedly dropped between four and seven years after the operation in knees with varus and valgus malalignment. Knees in neutral alignment performed better and declining annual survival rates were seen after six years. The most frequent type of failure in this report was gradually increasing instability with secondary loosening of the components.

There is good conformity of results (I, II and the latter study) except for the lack of a distinct plateau level. A plateau level (at 83 per cent survival) after six years was, however, also reported for Stanmore prostheses by Lettin et al. (1984).

Loosening of tibial unicompartement components

In the investigation (III) a sensitive indicator of potential radiographic failure was used. The criteria employed are only applicable in cases treated with a certain type of tibial component that has an indicator wire between the component and the bone-cement. The increased risk of deformation and loosening of thin tibial components was identified and this has been supported by others (Marmor 1976 and 1985, Shurley et al. 1982, Mallory and Danyi 1983). Today most manufacturers have removed thin components from the market.

Potential failure with impending loosening was not identifiable using knee scores. However, after an extended follow-up, analysis of revised failures readily demonstrated the clinical hazard of using a thin tibial component. The radiographic criteria did not include migratory loosening. In order to identify early subsidence, a sensitive and complicated method like stereophotogrammetry is needed (Ryd et al. 1983)

Nerve lesions after knee arthroplasty

An incidence of ten per cent below-the-knee nerve palsy and seven per cent subclinical nerve lesion was observed after knee arthroplasty for RA (IV). Predictive factors were the reduction of a flexion deformity and an alignment shift to varus. The duration of the tourniquet use was of no importance. Contributing factors such as swelling and pressure were proposed. Preoperative EMG could not predict nerve lesion.

Most reports on peroneal nerve palsy after knee arthroplasty show an average incidence of 2 (1 - 5) per cent. Rose et al. (1982) reported 0.87 per cent nerve palsies in a retrospective study of 2,626 consecutive knee arthroplasties. The type of

prosthesis and the condition treated were not stated. They did not find that the type of arthritis contributed to this disorder. Their incidence value could be compared with the 1.9 per cent nerve palsies in rheumatoid patients reported in the multicenter investigation (IV). Rose et al. found an increased incidence of nerve palsies in valgus knees and knees with flexion contracture, but no effect of the duration of the tourniquet use. Additional factors were tight splinting in extension and improperly padded splints. In some knees no causative factor was found. Obviously the genesis of nerve palsy is multifactorial.

In 35 high risk knees Rose et al. tried exploring and releasing the nerve during arthroplasty. Despite this precaution five developed nerve palsy. Nerve lesions are not always transient and may cause invalidity. High risk patients should be informed before the operation. Careful postoperative supervision with change of dressing and flexion of the knee as a measure of treatment for nerve symptoms is advocated.

No explanation for the high incidence of nerve palsies in the RA patients from Lund was found. The investigation was, however, prospective and focused on nerve lesions. There are also other thoroughly investigated materials with an incidence of 6 - 8 per cent in RA arthroplasties (Freeman et al. 1973, Andersen 1979).

Arthrodesis for failed knee arthroplasty

One of the reasons for a nationwide registration of knee arthroplasties was to make it possible to identify individual arthroplasties for retrospective and detailed analysis of certain problems. One such problem was arthrodesis for failed knee arthroplasty (V). Ninety-one cases were reviewed. Two-thirds finally fused and the functional follow-up clearly demonstrated the superiority of a fused over an unstable knee.

Review of the literature (V) shows that it is not as easy to achieve fusion in an arthrodesis for failed knee arthroplasty as in primary arthrodesis (Charnley and Lowe, 1958). The fusion rate has been reported to be lower after constrained than after semi-

or unconstrained prostheses. A lower fusion rate has not been reported after infectious failures (Rothacker & Cabanela 1983, Woods et al. 1983) and this was verified (V). Adequate bone stock is needed for the knee fusion and the loss is larger after constrained than after semi- or unconstrained prostheses (Hankin et al. 1981). This is a matter to consider when choosing between exchange arthroplasty with a larger prosthesis and knee fusion as a revision procedure.

Regarding the technique of fixation it has been stated earlier that failure to fuse was due to too short a fixation time (Brodersen et al. 1979), insufficient fixators (Vahvanen 1979) and technical inadequacies in the procedure (Hagemann et al. 1978). In the multicenter investigation (V) the less stable Charnley single frame fixator used for an average period of six weeks gave a lower fusion rate than the use of the Hoffmann-Vidal fixator with an average fixation period of three months.

Some of the limitations of the external fixators might be overcome by the use of a drill bit during insertion of the percutaneous pins to minimize heat necrosis of the bone (Matthews et al. 1984), threaded pins for better fixation (Bonnel 1974), titanium pins for better biocompatibility (Fischer 1983) and careful attention to soft tissues and pin tracts (Green 1983).

Stability of external fixators

The commonly used Hoffmann-Vidal fixator with six transverse pins has a much lower antero-posterior than lateral bending stiffness (Briggs & Chao 1982). Several ways of improving the antero-posterior stiffness have been advocated. Separation of pins and the use of larger diameter pins will improve stability (Briggs & Chao 1982). These alterations were previously not possible with standard Hoffmann components. Today new components have been added enabling pin separation. Other ways of improving stability are the addition of sagittal pins (Brooker & Hansen 1981, Fidler 1983) and ventral frames (Fischer 1983).

In the biomechanical study (VII) the improved antero-posterior

stability was demonstrated for the Hoffmann-Vidal fixator with additional sagittal pins. Further improvement was seen when the sagittal pins were fixed to a ventral frame of the author's design. The same improved stability was also achieved with a similar Ace-Fischer fixator. Updating the Hoffmann fixator, used at most clinics today, with a ventral frame is a competitive alternative to the Ace-Fischer device. Clinical studies have indicated a higher fusion rate when using fixators with improved antero-posterior stability (Rothacker & Cabanela 1983, Wade & Denham 1984).

Arthrodesis with an intramedullary nail

A method of performing primary knee fusion with an intramedullary nail was described as early as 1948 by Chapchal. He introduced the nail ventrally into the distal femur. In a review by Mazet and Urist (1960), the most common failures were femoral fractures through the introduction hole in the femoral cortex and breakage of the device at the level of the arthrodesis. Küntcher devised an extra-long nail to be inserted from the trochanter thus avoiding weakening of the distal femur. With a long nail the knee is fused in slight varus and full extension. A long intramedullary nail was used by Macys and Froimson (1973) for the treatment of a non-infected failed knee arthroplasty.

Four cases fused for septic knee arthroplasty failures using the Küntcher method were reported (VII). With a two stage procedure using gentamicin-beads infectious flare-up was avoided. The curvature of the femur in one patient made modification of the technique necessary. A ventral introduction of the nail into the trochanter gave a more dorsal position of the nail in the knee. A proximally curved nail was used in another patient with a short and strongly curved femur. The method described by Chapchal could not be used because of the already, by the infectious process, weakened distal femur. Reaming of the intramedullary canals is recommended to allow a larger nail diameter thus reducing the risk of breakage.

The attempted intramedullary nail arthrodeses in Lund (VIII) and in the multicenter investigation (V) from other surgical units resulted in fusion. The earlier reported complications with fracture through the introduction hole and breakage of the nail were seen in a few of these patients. Also the proximal migration of the nail was experienced twice in one patient. The complication was treated by a dynamic interlocking nail. A broken nail can be removed from the trochanter but a drill long enough to ream both femur and tibia has to be used before inserting a larger nail. Breaking up the arthrodesis could then be avoided.

Good results have also been reported for difficult arthrodeses using the fluted nail (Vander Griend 1983) and by the combination of a thin intramedullary nail and an external Charnley frame (Fahmy et al. 1984).

Arthrodesis after infectious failures

Three-fourths of the secondary knee fusions were performed because of infectious failures (V). The result of the treatment of the infection highly affects the outcome of an attempted arthrodesis (V). Removal of all foreign and infected material is important (Woods et al. 1983). The use of gentamicin-beads in a one- or two-stage procedure combined with systemic antibiotic therapy was the best way to combat infection. Other alternatives have been reported to be effective, as for instance delayed wound closure (Wade & Denham 1984) or open treatment with the Papineau technique (Green & Dlabal 1983). These methods were not evaluated.

For arthrodesis with external fixation the one-stage procedure, including removal of the prosthesis, fixation and insertion of gentamicin-beads, is appropriate. At a later stage the gentamicin-beads can be replaced by bone grafts. In cases where internal fixation is planned, a two-stage procedure with arthrodesis after an intermediary period of gentamicin-bead treatment and plaster fixation, is advocated. Foreign material should not be implanted until the infection is safely under control. An added

indication for the two-stage procedure is cases where the outcome of the intraoperative tissue cultures will aid in the decision whether an exchange arthroplasty or an arthrodesis should be performed.

Failure of attempted arthrodesis

A sufficient period of fixation is necessary to avoid failure (V). Wade and Denham (1984) suggested six months. Others have settled for less than half, although healing time has been reported to be at least four to five months even in uncomplicated cases (Hagemann et al. 1978, Brodersen et al. 1979, Thornhill et al. 1982). In the report on knee fusions from Lund (VIII) a four month period of initial fixation was used. If fusion was then not achieved, repeated cancellous bone grafting was used to induce healing (V and VIII). Provided that there is adequate fixation, the chance of fusion is as good at the second attempt as at the first operation (V and VIII).

Centralized treatment

Knee fusion after failed knee arthroplasty is a demanding procedure. Experience and special equipment are needed. Four surgical units reporting more than five patients each achieved fusion in more than three-fourths, compared with the remaining units with fusion in less than half. One way of gathering experience and improving results would be to centralize knee failures to clinics specialized in prosthetic surgery and its complications.

Knee arthroplasty is still at an experimental stage with constant changes in the prosthetic design, fixation methods and surgical technique. This large scale experiment on humans should be carefully followed. When a knee arthroplasty fails the unfortunate must be offered a safe way back to an established treatment for advanced gonarthropathy, which means an arthrodesis.

GENERAL SUMMARY

A prospective nationwide multicenter study of knee arthroplasties has been ongoing in Sweden since October 1975. 4,505 arthroplasties for OA and 3,495 arthroplasties for RA have been recorded and reviewed one, three and six years after the operation. Using a life table technique, the six year probability of the prosthesis remaining in situ was calculated. This probability ranged in OA from 65 per cent for hinge prostheses to 90 per cent for medial unicompartment prostheses. Bi- and tricompartment prostheses produced intermediate results (87 per cent). In RA results varied from 72 per cent for medial unicompartment prostheses to 90 per cent for bi- and tricompartment prostheses. The main reason for failure was loosening and infection. The probability of a revised infection at six years was two per cent in OA and three per cent in RA. Most revisions were performed with a tricompartment prosthesis. The probability of a knee fusion as a primary revision procedure was two per cent at six years.

During a fifteen year period 498 primary knee arthroplasties for chronic arthritis were performed in Lund. Ninety arthroplasties were revised, with a new prosthesis in 81, an arthrodesis in eight and an above knee amputation in one. The probability of the prosthesis remaining in situ at six years was 76 per cent for tibial hemi-, unicompartment and hinge prostheses respectively and 82 per cent for stabilized prostheses. Continuous deterioration was seen for tibial hemiprostheses after six years. There were no failure in tricompartment prostheses and this was ascribed to the improved surgical technique and to some extent the improved prosthetic design.

Radiographic signs of deformation and loosening of the tibial component in knee arthroplasties with unicompartment prostheses occurred in one-third of 87 RA knees within 2 years and in one-fifth of 107 OA knees within 3 years after the operation. Compared with thicker components significantly more 6 mm components in RA, and 6 and 9 mm components in OA became deformed and loose. There was no difference in the clinical assessment of the knees with and without deformed components.

In the group with initially asymptomatic loosening 12 RA knees within 4.5 years and 3 OA knees within 4 years developed pain on weight-bearing and had to be reoperated. One OA patient, revised for secondary OA, had loose components without any radiographic signs. Knees fitted with 6 mm components more often required reoperation because of loosening than did those with thicker components.

Forty-two consecutive knee arthroplasties for RA were examined pre- and postoperatively for signs of below-the-knee nerve lesions. Sixteen of these knees were also studied neurophysiologically (EMG). Four had peroneal nerve palsy, three early and one late. A further three knees had only EMG signs of nerve lesion. The predisposing factor was correction of flexion contracture of more than 10 degrees, especially when combined with varus change in alignment. Preoperative EMG could not predict nerve lesion. Forty-three nerve palsies (2 per cent) were recorded in 2,273 RA knee arthroplasties in the multicenter investigation.

Ninety-one patients with attempted arthrodesis after failed knee arthroplasty were identified in the multicenter investigation. Three-fourths of the failures were caused by infections. Two patients expired from infection and four had amputations. Fusion was achieved in only half of the 108 attempts in 91 knees. The fusion rate was relatively high after unicompartment prostheses, in cases with sustained rigid fixation, or in cases where infection was brought under control at arthrodesis. Rigid fixa-

tion was best achieved with an external double frame or an intramedullary nail. Repeated attempts were worthwhile. Removal of all foreign material, eradication of the infectious lesion, and insertion of gentamicin beads seemed to be the best way to combat infection. The treatment of prosthetic failures should be referred to centers with a special interest in knee arthroplasty.

Four case reports illustrated the technique of intramedullary nail arthrodesis in the treatment of infected knee arthroplasties. A two-stage procedure is recommended, first eradication of all foreign and infected material and temporary use of gentamicin beads and four weeks later intramedullary nail fixation and massive bone transplantation.

In a biomechanical study, external fixators were tested for stability in a material testing machine using synthetic bones. The anteroposterior bending stiffness was significantly improved when sagittal pins connected to a ventral compression rod were added to a Hoffmann-Vidal fixator. Stiffness was still more improved when sagittal pins were connected to ventral frames as in a modification of the Hoffmann-Vidal or the similar Ace-Fischer fixator.

Nineteen out of twenty consecutive patients treated by arthrodesis for failed knee arthroplasty in Lund gained sound fusion and one patient refused a second-stage operation. Infected knees had a two-stage procedure with temporary insertion of gentamicin beads. All infections healed. Seven arthrodeses using external fixators resulted in two temporary failures. Of 10 primary attempts at arthrodesis with an intramedullary nail, nine were successful. The tenth fused after two more attempts by the same method. The two failures in external fixation and two failures done elsewhere were successfully fused with intramedullary nails. Delayed union in three cases fused after prolonged fixation and repeated bone grafts.

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